Appendix C

Radiological Calculation Methods

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Radiological exposure rate calculations were made in support of WAG 1, OU 1-10 Interim Sludge Storage Facility Design. The following sections describe the methodology and assumptions for performing these calculations. Additionally the following items are included as attachments to this appendix:

- Attachment 1 – TAN Warm Shop drum layout and detail of Duratek shielded drum overpack
- Attachment 2 – Individual V-tank Sludge Exposure Calculations
- Attachment 3 – TAN Warm Shop Drum Layout Exposure Calculations
- Attachment 4 – Form 431.01, Radiological Control Design Review.

Exposure rates were calculated using the MicroShield computer code to calculate exposure rates from the individual V-tank sludges (i.e. V-1, V-2, V-3, and V-9) in waste containers and in shielded overpacks. Additionally, general area exposure rates were calculated for the drum layout provided in Attachment 1 to this Appendix.

C.1. ASSUMPTIONS

The following assumptions were made during the exposure rate calculations:

- The sludge materials used for input in the MicroShield case files was constructed using analytical data from the 1996 sampling of the V-tanks. The same material was used for tanks V-1, V-2 and V-3. A separate material file was created for the V-9 sludge
- The density of the V-1, V-2, and V-3 sludge was taken as 1.02 g/cm^3, from 1996 data
- The density of the V-9 sludge was taken as 1.3 g/cm^3, from 1996 data
- The radionuclide source term was developed from the 1996 data set. This data set was decayed from June 1996 to August 2001, a period of 5.2 years
- Preliminary calculations showed that >99% of the exposure was attributed to Co-60 and Cs-137/Ba-137m; therefore, the exposure calculations presented here consider only Co-60 and Cs-137/Ba-137m.

For the exposure rate calculations for the drum configuration shown in Attachment 1, the following assumption was also made:

- The sludges from tanks V-1, V-2, V-3 and V-9 were homogeneously distributed amongst the 100 drums, with 20 gallons of sludge per drum.

C.2. METHODS AND RESULTS

Exposure rates, in air, were calculated using the MicroShield computer code. Exposure rates for individual drums of sludge from each of the four V-tanks were calculated, as were general area exposure rates for the TAN Warm Shop floor using the assumptions listed above. Information regarding the waste geometry and physical characteristics, shielding materials and radiological source terms were input into MicroShield. Dose points of interest were selected based on anticipated waste handling and waste inspection practices.

C.2.1 Individual V-Tank Drums Calculations

As stated previously, exposure rates were calculated separately for the sludges from each V-tank. The amount of sludges in a single drum from the individual V-tanks varied. These quantities are shown in Table 1 below.

Table 1. Quantities of sludge in waste drums from the V-tanks.

Drum Waste Designation	Waste Volume, gallons
V-1	49
V-2	42
V-3	15
V-9	50

These quantities were calculated from the 1996 analytical data set, based on the restriction that each drum could contain a maximum of 4 Ci of Sr-90. Using these volumes, and decay corrected maximum concentrations, total activities for the primary radionuclides of interest, Co-60, Cs-137/Ba-137m, were calculated. Table 2 below lists the quantities of radionuclides input into MicroShield for each V-tank sludge drum.

Table 2. Radionuclide source term for individual V-tank wastes.

Drum Waste Designation	Activity per Drum, Curies
V-1	
Ba-137m	2.1896
Co-60	3.7159×10^{-2}
Cs-137	2.3146
V-2	
Ba-137m	1.6749
Co-60	5.0347×10^{-2}
Cs-137	1.7705
V-3	
Ba-137m	4.2625×10^{-1}
Co-60	8.1871×10^{-3}
Cs-137	4.5059×10^{-1}
V-9	
Ba-137m	1.2702
Co-60	1.3906×10^{-1}
Cs-137	1.3427

The radionuclide activities in Table 2 are the maximum decay corrected activities for each V-tank sludge, representing the worst case scenario.

The sludge volumes and radionuclide activities listed in Tables 1 and 2 above were input into MicroShield along with the drum and overpack material properties and dimensions. The drums simulated in these calculations were standard 55-gallon steel drums. The Duratek shielded overpack incorporates inner and outer steel shells with a layer of lead 1.625-inches thick between the layers of steel as detailed in Attachment 1. Tables 3 and 4 below summarize the MicroShield calculations, detailing the calculated exposure rates in air for the sludge in the drum only and with the drum packaged in the shielded overpack, at contact with the drum, and at a distance of 1-foot.

Table 3. Individual drum only exposure rates.

Drum Waste Designation and Exposure Point	Exposure Rate, mR/hr
V-1	
Contact with drum, midpoint of sludge height	5,436
1-foot from drum, midpoint of sludge height	1,403
V-2	
Contact with drum, midpoint of sludge height	4,952
1-foot from drum, midpoint of sludge height	1,177
V-3	
Contact with drum, midpoint of sludge height	2,330
1-foot from drum, midpoint of sludge height	330
V-9	
Contact with drum, midpoint of sludge height	3,287
1-foot from drum, midpoint of sludge height	872

Table 4. Exposure rates for sludges packaged in shielded overpacks.

Drum Waste Designation and Exposure Point	Exposure Rate, mR/hr
V-1	
Contact with overpack, midpoint of sludge height	8.8
1-foot from overpack, midpoint of sludge height	4.3
V-2	
Contact with overpack, midpoint of sludge height	11.3
1-foot from overpack, midpoint of sludge height	5.1
V-3	
Contact with overpack, midpoint of sludge height	4.3
1-foot from overpack, midpoint of sludge height	1.3
V-9	
Contact with overpack, midpoint of sludge height	17.8
1-foot from overpack, midpoint of sludge height	8.5

As can be seen from Tables 3 and 4 above, the exposure rates are reduced significantly when the sludge is placed in the shielded overpacks.

C.2.2 TAN Warm Shop Floor Loading Exposure Rate Calculations

After the V-tank sludges are placed into the drums and shielded overpacks, the drums will be placed into interim storage inside the TAN Warm Shop as detailed in the drawing in Attachment 1. As part of the requirements for storage of CERCLA waste, the waste storage area and individual containers must be visually inspected by a qualified individual on a weekly basis. As a result, the OU 1-10 interim sludge storage facility design for the TAN Warm Shop required exposure rate calculations for selected locations inside and around the drum storage area. The drum layout, as depicted in Attachment 1 also shows the exposure points of interest. The first exposure point is in the center of the Warm Shop floor, between the two rows of drums. The second and third exposure points are located at a distance of 2-feet from the exterior of the concrete barriers that will be placed as temporary shielding around the perimeter of the drum storage area.

At this point, the positioning of specific drums inside the TAN Warm Shop (i.e. V-1, V-2, V-3 or V-9) is unknown. As a result, it was assumed for the purposes of these calculations, that the 2,000 gallons of sludge would be homogenized, and equal amounts of sludge, 20-gallons, would be placed in each drum. As a result, the radionuclide activities were weighted in accordance with the percentage of the total of 2,000 gallons of sludge represented by each V-tank. The assumed quantities of sludges from the V-tanks are as follows: V-1 at 540 gallons (27%), V-2 at 540 gallons (27%), V-3 at 620 gallons (31%), and V-9 at 300 gallons (15%). Table 5 below lists the radionuclide activities used for the TAN Warm Shop floor loading exposure rate calculations.

Table 5. Radionuclide source term for homogenized sludge used in floor exposure rate calculations.

	Radionuclide		Activity per Drum, Curies	
	Homogenized Waste			
	Ba-137m		7.6717×10^{-1}	
	Co-60		2.277×10^{-2}	
	Cs-137		8.1096×10^{-1}	

Exposure rates in air were calculated for each of the exposure points of interest at a height of 1-meter above the TAN Warm Shop Floor. Exposure rates were calculated for each drum in the two rows closest to the center of the floor (Exposure Point #1), and for each drum in the rows closest to the concrete barriers for Exposure Points #2 and #3. Consideration was also given to the drums in the rows that are shielded by the closest rows; however, preliminary calculations showed that the exposure from the distal rows is negligible.

The calculated exposure rates were obtained by summing the individual exposure rates from each drum in the proximal row(s), neglecting the partial shielding provided by neighboring drums in the same row. As such, the exposure rates presented in Table 6 below are conservatively high.

Table 6. Exposure rates 1-meter above the TAN Warm Shop floor for selected exposure points.

Exposure Point	Exposure Rate, mR/hr
1 - Center of drums, TAN Warm Shop	2.7
2,3 - Center of drum row, 2-feet outside concrete barrier	7.6×10^{-4}

C.3. CONCLUSIONS

The calculations presented here represent estimates of exposure rates based on specific assumptions. It is anticipated that actual exposure rates may vary; as a result, field measurements of exposure rates should be made in the field, and appropriate radiation protection measures implemented based upon field measurements and conditions. Additionally, at the discretion of TAN RADCON personnel, additional area monitoring TLDs may be placed in areas adjacent to the TAN Warm Shop to verify that personnel exposures are maintained as low as reasonably achievable.